

Comparison of the Spectrum, between C and D, of a Sun-spot, observed May 27, 1884, with another of May 7, 1889. By Rev. S. J. Perry, D.Sc., F.R.S., and Rev. A. L. Cortie.

As the observations of the spectra of sun-spots at the red end of the spectrum have been rare during the time of minimum, we give in the present paper the results obtained on May 6 and 7 of the present year. All the lines between D and *w.-l.* 6474·85, very near C, were carefully examined, and their widening estimated in tenths of the normal breadth of the respective lines. The instrument used was the Browning automatic spectroscope, a dispersion of twelve prisms of 60° being employed. The definition was good, and the lines were all identified on Angström's map. The spot had appeared on the limb on May 5, and disappeared about the 11th. The general absorption on the 6th was moderate, and on the 7th the spot was evidently breaking up. The following table contains a comparison of these observations, with the spectrum of a sun-spot near the epoch of spot maximum, taken under precisely the same conditions on May 27, 1884. This latter spot was very black, with a dark general absorption. Its spectrum had been previously observed on April 4, and it had reached its quiet stage after two solar revolutions. In Table I. the first column gives the wave-lengths of the lines taken from the British Association Catalogue (1878), and in the second and third columns are the observed amounts of widening in the two spots. The lines seen bright in the chromosphere by Professor Young are marked by an asterisk. In the remarks, A., B., F., S., K., L. and D. refer to the maps and numbers of Angström, Burton, Fievez, Piazzzi Smyth, Kirchhoff, Liveing and Dewar. In Table II. are collected the results for the different metals. In drawing up this table the coincidences have been taken from Angström's map, and the British Association Catalogue (1878). A few lines also have been admitted from Watts' Index of Spectra, when the positions were very close, always less than one tenth-metre.

TABLE I.

Lines between C and D observed in two Sun-spots.

Wave-length.	1884, May 27,	1889, May 6 and 7.	Remarks.
6562·10 C	0	0	
45·40	0·4	...	
*15·80	0·5	...	
11·64	
6498·25	0·6	...	
*96·31	0·4	...	

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Wave-length.	1884, May 27,	1889, May 6 and 7.	Remarks.
94.18	
92.41	0.4	...	
90.07	0.4	...	
81.18	0.5	...	
79.01	0.5	...	Comparison of the two spots begins.
74.85	...	0.8	
71.85	0.3	1.0	Seen as single.
70.75			
68.78	0.5	1.0	
67.14	0.3	...	
63.74	0.8	...	
*61.98	0.4	1.0	A basic line. Resolved by L. and D. Fe the less refrangible. F. resolves. Seen as double with 12 prisms.
*54.0	0.5	0.8	A double.
	1.0	...	Faint line.
49.29	0.4	1.0	Ca more refrangible: L. and D.; F. resolves.
38.35	0.4	0.7	Cd more refrangible: L. and D.; F. does not resolve.
31.73	...	0	
*30.12	0.2	1.0	
20.63	0.2	0.6	
19.17	0.3	0.6	
*15.90	0.5	0.3	
14.10	0.5	0.3	
10.62	0.5	0.5	
07.38	0.4	0.5	Fe more refrangible: L. and D.; F. resolves. Seen as double with 12 prisms.
		0.8	Faint line.
		0.8	Faint line.
*6399.28	0.3	0.5	
		0.5	A double, about 6383.5 F.
*92.87	0.2	0.5	Both F. and S. draw as a double. Often so seen.
79.99	0.4	0.3	
77.58	0.3	...	
	0.6	...	Probably F. 6369.5.
64.49	0.7	0.3	In A.'s catalogue. Not in his map.
61.41	0.5	0.3	
57.92	0.3	0.2	
54.28	0.3	0.2	

Wave-length.	1884, May 27,	1889, May 6 and 7.	Remarks.
		1.0	A double.
*6346.34	0.3	0.4	
43.40	0.2	0.5	
38.21	0.2	0.3	
36.61	0.2	0.3	
34.54	0.2	0.3	
	0.8	1.0	Not in A.
	0.7	1.0	Not in A. Probably B. 6327.0.
21.81	<i>d</i>	0.5	Only darkened May 27, 1884.
18.41	0.4	0.3	
17.17	0.4	0.6	
14.18	0.4	0.4	
09.78	0.5	0.5	May 6, 1889. Double or triple. A. draws as a faint line.
05.0	...	0.5	Wave-length doubtful. A double. F. has the line.
01.88	1.0	0.3	Black and close double.
01.03	0.1		
00.5	...	0.3	In A.'s map. Not in his catalogue.
6298.74	0.4	0.3	
96.95	0.4	0.5	
	<i>d</i>	...	Probably K. 801.5. Darkened May 27, 1884.
94.27	0.4	0.4	A double. A. has a line at 6293.5 in his map.
91.78	0.3	0.5	
90.31	0.3	0.4	
86.69	0.8	0.2	
84.99	1.0	0.6	
81.81	0.6	0.8	May 6, 1889. Three well-marked lines seen in the α group, surrounded by a hazy band.
79.79	0.5	0.8	
77.09 ^a	0.3	0.4	
76.32?	1.0	1.0	A faint line just preceding a group.
70.16	<i>d</i>	0	
69.35	<i>d</i>	0.5	
	1.0	...	
	1.0	...	
64.31	0.3	0.3	
62.68	May 6, 1889. Could not be seen at all.
60.37	0.5	...	
57.84	0.8	1.0	Close double.

June 1889.

Spectra of Sun-spots.

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Wave-length.	1884, May 27,	1889, May 6 and 7.	Remarks.
55.51	0.4	0.8	
53.40	0.4	0.8	
51.76	0.4	0.8	
46.55 }	0.4	0.6	
*45.62 }		0.6	
43.49 }	0.5	0	May 6, 1889. Very much widened on more refrangible side.
42.60 }		3.0	
40.51 }	0.5	1.0	Double seen as one line.
39.42 }			
*37.55 }	0.3	0.8	{ Triplet hard to separate in spot. Has a fuzzy appearance.
37.09 }			
36.33 }			
*6231.72	0.4	0.5	
29.91	0.2	0.6	
28.35	0.5?	1.0	
25.62	0.8	0.8	
22.57	1.0	0.8	
21.10	1.0	0.8	
*18.46	0.3	0.5	
15.67	0.5	1.0	
*14.30	0.5	0.6	
12.55	0.2	0.8	
09.3	1.0	...	A line in A.'s map, but neither in his nor B.'s catalogue. Could not be seen May 6, 1889.
	0.8	...	F 6203.5.
*6199.85	0.3	0.5	
	1.0	1.0	Faint line not in A.
*90.71	0.4	0.5	
87.26	0.8	0.8	
	0.8	0.8	6185.4 in A.'s map; not in his catalogue.
	1.0	1.0	Faint line. F 6182.0?
79.46	0.4	0.5	
75.95	0.5	0.5	
74.51	0.5	0.6	
72.49	0.2	0.5	
69.59	0.5	0.6	
*68.48	0.5	0.8	
65.62	0.8	2.0	Widened very much in penumbra, May 6, 1889.

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
63.95	0.8	1.0	
62.69	0.5	0.5	
*61.40	0.3	0.6	
60.23	0.8	0.8	
56.90	0.2	0.5	
54.41	0.5	0.8	{ A close triplet. Difficult to separate in spots.
53.89			
53.33			
50.68	0.5	0.5	
	1.0	0.8	Not in A. or F.
*48.28	0.2	0.5	
*46.76	0.2	...	Line could not be seen at all, May 6, 1889.
44.09	0.2	0.8	
*40.81	0.1	0.6	
36.82	0.2	0.6	
*35.82	0.2	0.6	
	1.0	2.0	Faint spot line. Not in A. or F.
30.59	0.4	0.8	
28.61	0.2?	0.8	
27.00	0.5	0.5	
25.29	0.5	0.8	
23.92	0.2?	0.8	
*21.34	0.4	0.5	Co less refrangible: L. and D. F. does not resolve.
6118.93	0.5	0.8	Very faint line.
15.51	0.3	0.3	Ni lines sharp, thin, dark lines.
*10.11	0.5	0.8	
07.36	0.2	0.3	
04.58	1.0	0.8	
*C1.92	0.4	0.6	Ca more refrangible: L. and D.
6099.08	0.6	0.5	
95.20	0.3	0.5	The identification of the group of faint lines between 6101.92 and 6077.8 is somewhat doubtful. A. gives ten lines, K. eleven, B. twelve, F. sixteen, and S. eighteen. With 12 prisms and excellent definition, fourteen lines have been seen, the grouping agreeing much more with the map of S. than with that of F.
92.42	0.5	...	
90.59?	0.5	1.0	
88.42	0.5	...	

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
86.69	0.5	0.7	
85.1	<i>a</i>	0.5	
*84.0?	0.6	0.5	
81.3	0.5	0.5	
80.4	0.5	0.5	
77.80	0.3	0.5	F. doubles.
75.87	0.5?	...	Not seen, May 6, 1889.
*64.70	0.4	0.4	Fe less refrangible: L. and D. F. doubles.
	1.0	1.0	6061.7 F.
55.29	<i>a</i>	0.3	
53.28	0.8	0.8	
		1.0	Spot line 6044.79 F.
41.37	0.2	0.3	
	1.0	2.0	6039.4 F.
26.14	0.4	0.5	
23.16	0.3	0.5	
20.91	0.5	0.5	
*19.33	0.3	0.5	A double, F. 933.8 K.
15.81	0.4	0.5	
12.68	0.5	0.5	
11.42	...	1.0	
07.65	0.4	0.2	
07.2	...	0.4	B.'s catalogue. 940.4 K.
		1.0	Spot line about <i>w.-l.</i> 6004.
02.25	0.4	0.2	
	1.0	1.0	A. has a Ti line in map at 5998.5, but not in his or B.'s catalogue.
5997.08	0.5	0.2	
96.44	
*90.20	...	0.4	Generally not able to separate.
89.89	...		
88.10	...	0.4	A double.
86.35	0.4	0.2	
84.35	0.8	.3	
83.01	0.8	0.2	
77.27	1.0	1.0	
76.23	0.3	0.3	
74.79	0.5	0.3	
5970.44	...	0.3	
69.22	...		

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
67.35	0.8	0.5	
65.9	0.8	0.5	In A.'s map, but not in his catalogue.
57.22	0.3	0.3	
55.63	...	0.5	
53.94?	...	1.0	
51.96	0.5	0.5	
47.62	0.5	0.3	
45.	...	0.5	
44.98	...		
43.62	...		
41.71	...	0.5	Marked in A.'s map, but not in his catalogue.
40.9	...		
40.43	...		
37.44	...	0.8	
34.03	0.5	0.3	
31.76 }	1.0	0.5	Drawn slightly out of position in A.'s map.
31.18 }			
29.46	0.2	0.3	
27.37	0.2	0.5	
24.02 }	0.5	0.5	Two lines generally seen as one thick one.
22.99 }			
21.69			
20.87	In A.'s map and catalogue, and in B.'s catalogue, but not seen.
19.09 }	0.5	0.5	{ A dark band 5918.4 is not marked in A.'s catalogue, but in his map.
18.4 }			
17.51 }			
14.60	0.5	0.8	
*13.30	0.2	0.1	
09.72	0.7	...	
04.56	0.5	0.2	A bright line or space about 5900. May be the effect of contrast.
5899.10	0.8	0.2	
*95.13	0.3	0.4	
92.10	0.4	0.2	
90.78	...	0.5	
*89.12	0.3	0.4	

TABLE II.

Lines widened one-half or more of their normal breadth.

Substance.	1884, May 27.	Bright in Chromosphere.	1889, May 6 and 7.	Bright in Chromosphere.
Iron	8	0	27	10
Titanium	12	1	12	2
Sodium	2	0	2	0
Calcium	3	1	8	5
Barium	2	1	4	3
Nickel	1	0	1	0
Manganese	2	0	3	0
Strontium + Fe	0	0	1	0
Cobalt + Ca	0	0	1	1
Antimony + Fe	0	0	2	1
Lithium + Ca	0	0	1	1
Cadmium + Ca	0	0	1	0
Zinc	1	0	0	0
Unknown	12	1	18	1
Unknown and faint	44	1	48	0

The above tables show that the widening of the faint unknown lines of the solar spectrum is common to the minimum and to the maximum sun-spot period. We would especially call attention to the faint lines at *w.l.* 6039.3 F, 6053.28 A, and 6061.7 F, which are hardly traceable in the ordinary spectrum, and yet have been considerably widened in both sun-spots.

On the other hand the number of metallic lines which are among the most widened lines is much greater in the minimum than in the maximum spot. In the case of iron, for instance, the numbers are as 27 to 8. Again, none of the most widened iron lines of the maximum sun-spot have been recorded as bright in the chromosphere, while no less than ten of these lines in the minimum spot have coincident bright lines. The total number of lines seen bright in the chromosphere, which have also been observed among the most widened lines in the two spots, are for the maximum spot only five, but for the minimum spot twenty-four.

Another noticeable difference is that some lines of the maximum spot were widened far out into the penumbra, the most marked being *w.l.* 5892.10, 5977.27, 6172.49, F. 6039.4, and F 6203.5. But in the minimum spot only one line was thus affected, 6165.62.

In Ångström's map there is a line at *w.l.* 6209.3, of about intensity 2 of Kirchhoff's scale. This line is not in his catalogue.

nor in that of the British Association, nor is it drawn in the maps of Kirchhoff, Piazzzi Smyth, or Fievez. It could not be seen on May 6, and was again carefully searched for with the same result on May 21, 1889. Yet it is marked as widened in the spot of May 27, 1884.

The Nebula G. C. 2091. By E. E. Barnard, M.A.,
Astronomer of the Lick Observatory.

In the *Observatory* for April 1885 Mr. Sadler called attention to this nebula, and brought forward seemingly strong proof of motion. This is the nebula in which the double star *h* 2529 was observed, according to Sir John Herschel, twice in 1830 and once in 1831.

The nebula has also been observed by D'Arrest, and at Parsonstown; but it is not clear from the records that any of the observers since Herschel saw the double star to recognise it as such, though it is mentioned by them.

Mr. Burnham observed this nebula in 1879 and 1882, and measured the position-angle and distance from the tenth-magnitude star south of it. His measures are:

1879.225	8°.3	18".96
1882.195	7°.5	18".96

He estimated the magnitude of the star as 10, and the nebula as 12.

On March 5 of this year I examined the nebula with the 12-inch, and measured the position-angle and distance from the tenth-magnitude star—

1889.178	7°.8 (5 Obs.)	18".96 (6 Obs.),
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the distance coming out singularly enough the same as Mr. Burnham's two measures.

The nebula was small, round, and brighter in the middle, and quite easy to measure. I estimated the equivalent light to be of the twelfth magnitude.

On March 21, 23, and 24 Mr. Burnham and I examined this nebula with the 36-inch refractor. It was found to have an extension preceding and slightly north. This resembled a faint tail and was about 25" long. In this extension was a faint condensation, which at first gave the appearance of a distinct nebula separated from the principal one. There was also a very faint extension for 10" following and slightly south. Several times an excessively faint and difficult nucleus was seen, which did not appear to be stellar. A very faint star was thought to be involved in the preceding end of the tail, but it could not be seen steadily enough to make its existence certain. On each night the tenth-